RHIC Vacuum Upgrade

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November 8, 2004

Outline

- Layout of Vacuum Systems
- Upgrade in 2001 – 03'
  - Increased In-situ Bake Sections
  - Installed Electron Detectors and Solenoids
- Upgrade in 2004
  - Installed Anti-Grazing Rings
  - Cold Bore Improvement
  - NEG Coated Warm Beam Pipes and Activation
- Future Plan / Summary
  - NEG Coating of Expt. Area Beam Pipes
  - Summary

Vacuum System Layout

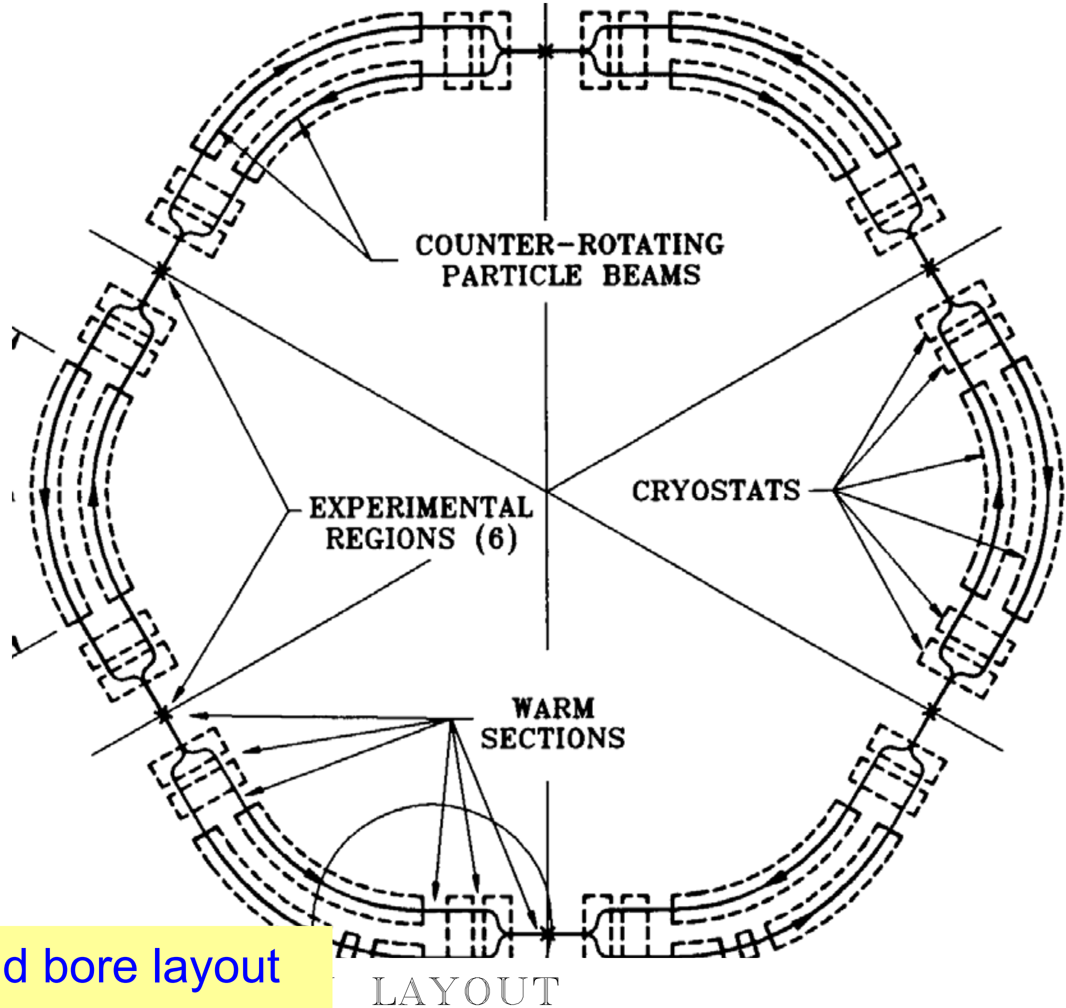
Six sextants

40 cold vacuum sections (6.4 km)

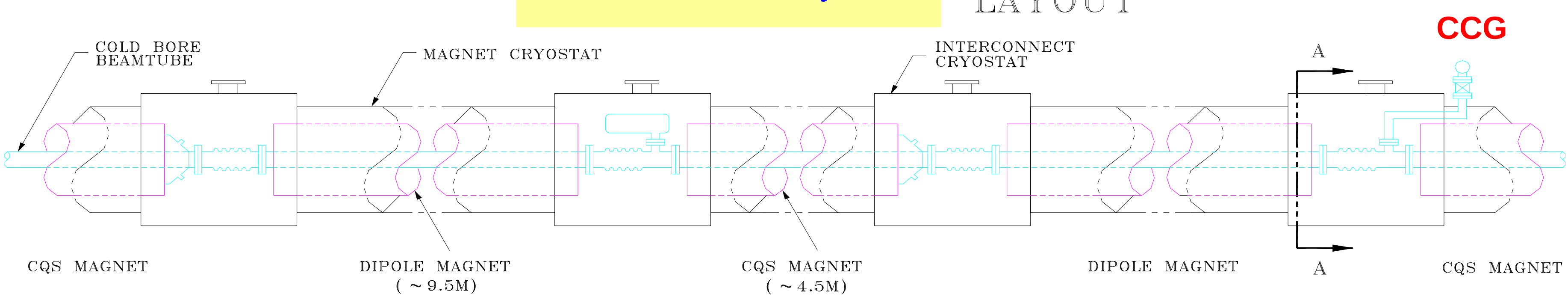
- 12 Long Arcs of ~500m each
- 24 triplets sections of 20m each
- 4 at injection areas
- CCG every 30m

46 warm vacuum sections (1.2 km)

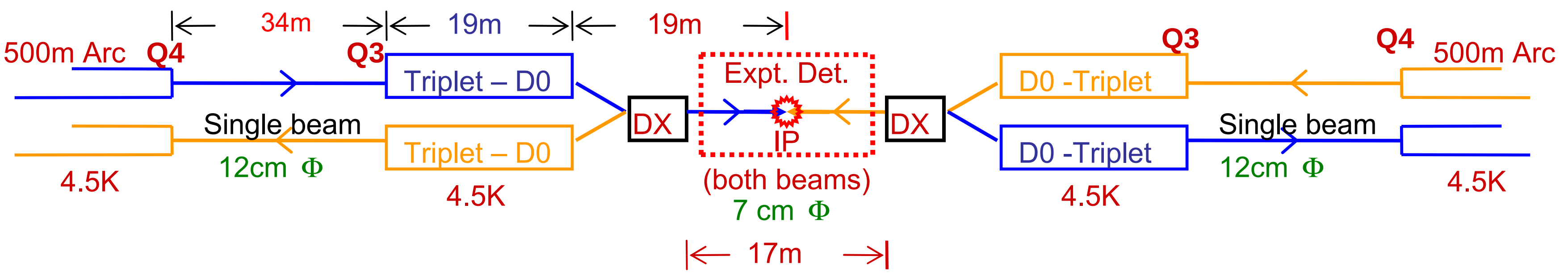
- 24 Q3-Q4 insertions
- 12 DX-D0, 6 IR, …



Arc cold bore layout



Layout of Warm Vacuum Sections – IR + Insertions



Length of Warm Sections from 17 – 34 m

Pumped with ion pumps and titanium sublimation pumps every 10 - 17 m

Linear conductance of 40 – 200 *l.m*/s for CO (Φ = 7 – 12cm)

P_{AVG} / $P_{Pump/gauge}$: < 8 (H_2) – 28 (CO) for Φ = 7cm (IR region)

< 2.6 (H_2) – 7 (CO) for Φ = 12cm (Q3 – Q4)

Most sections were In-situ baked up to 250°C x > 48 hours ⇒low 10^{-11} Torr

7 sections (mostly @ RF regions) were not baked – low 10^{-9} - 10^{-10} Torr

Upgrade in 2001 – 03'

Increased In-Situ Baked Warm Sections from ~ 35% to ~ 85%

Comparing Pressure Rise (ΔP) of **Baked** vs **Not Baked**

Red:	**baked**
Blue:	**partially baked**
Black:	**not baked**

ΔP during #5350 (last ramps) as example

IR4 > IR12 > IR10 > IR2 > IR6 > IR8

bi8 > bo2 > bi4 > bi12 > bo10 > bo11 > bi1 > bo3 > bo6 > bo7 > bi5 > bi9

yo1 > yo4 > yi2 > yo12 > yi7 > yi10 > yo9 > yo5 > yi6 > yi11 > yi3 > yo8

General Trend:

Lower P_o $\Rightarrow$ lower ΔP_{beam}

Baked better than partially baked, and better than not baked

- Various beam components were partially baked
  - DCCT-60ºC, WCM & Schottky-100ºC, IPM & stochastic cooling <120ºC…..
- Need more thorough bake, and at higher T and longer period
- RF cavities, polarimeters, jet… are not bakeable

Upgrade in 2001 – 03'

Electron Detectors

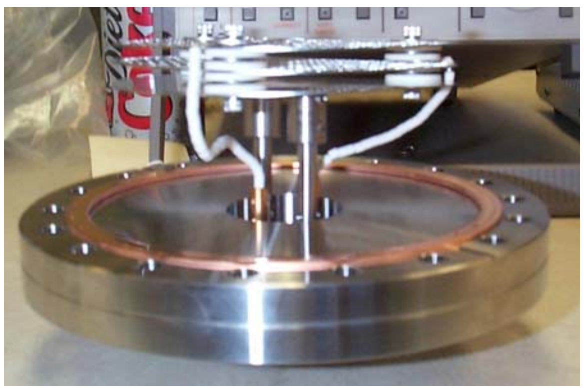
to study I_e, E_e ...

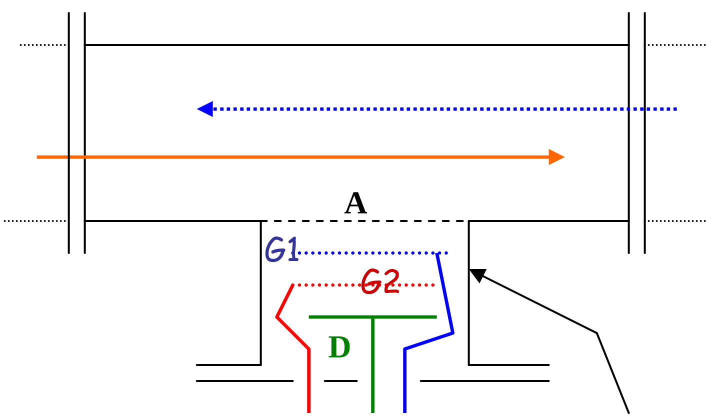
Install 12 custom units in 2002

Large electrodes with A = 75cm², ~70º

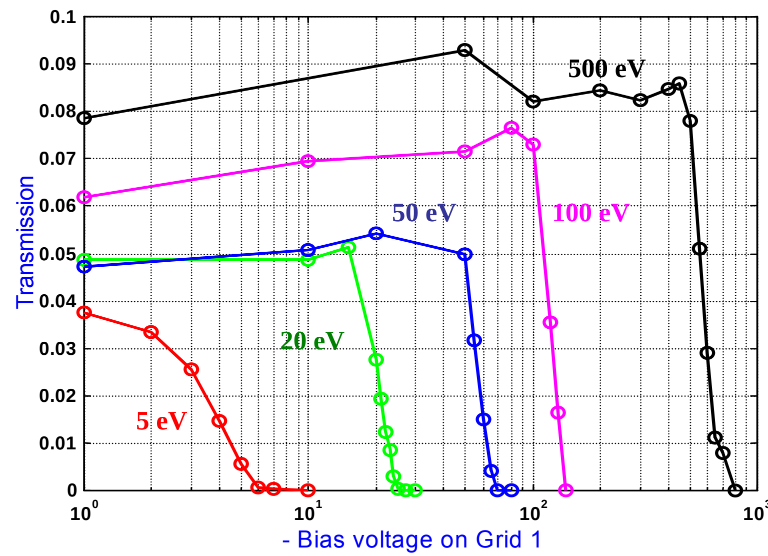
Well shielded from beam image current

Transmission efficiency of 6 ± 2%





Calibration with electron gun



Detector Configuration:

A: RF shield, ~ 20% transparency

G1: retarding electrode (< - 1kV)

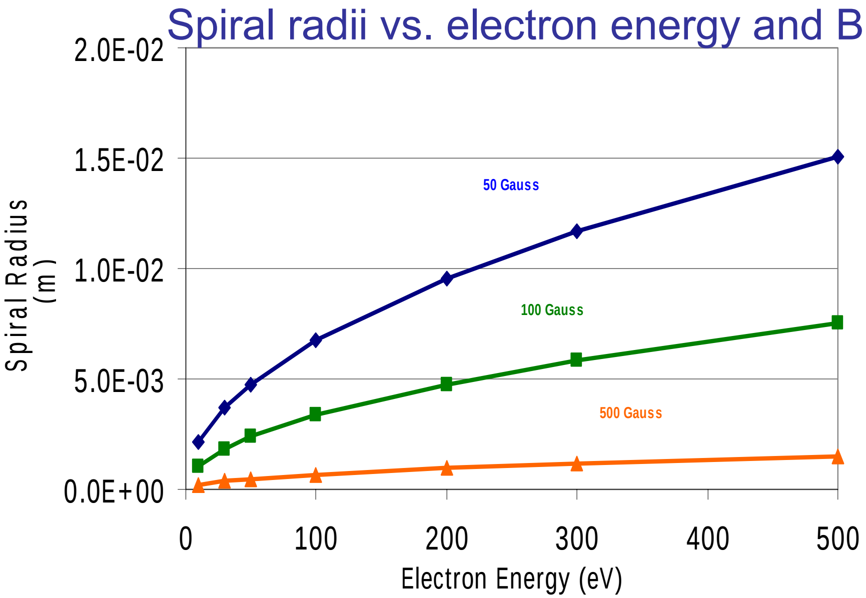
G2: anode grid (< 1 kV)

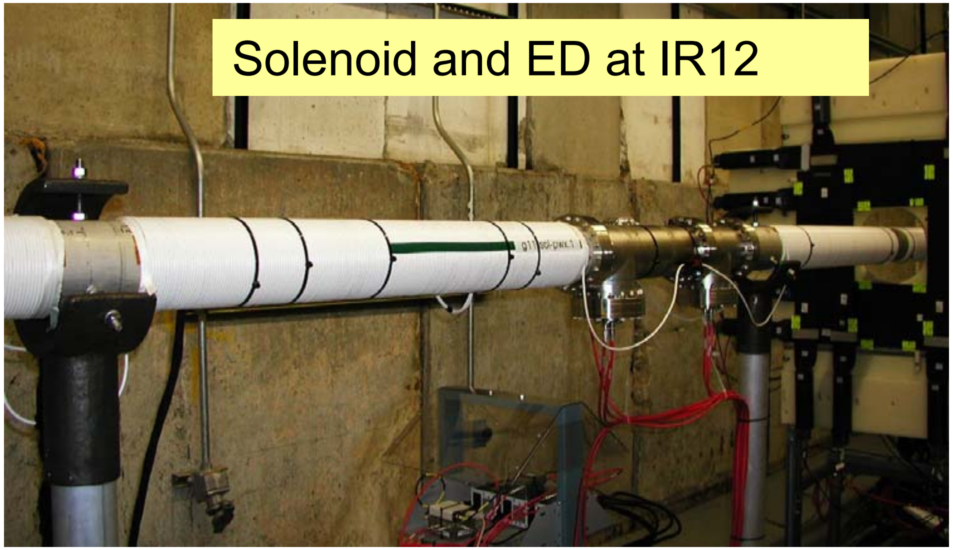
D: electron collector plate

Solenoids

To confine the electrons on a spiral orbit near the chamber wall

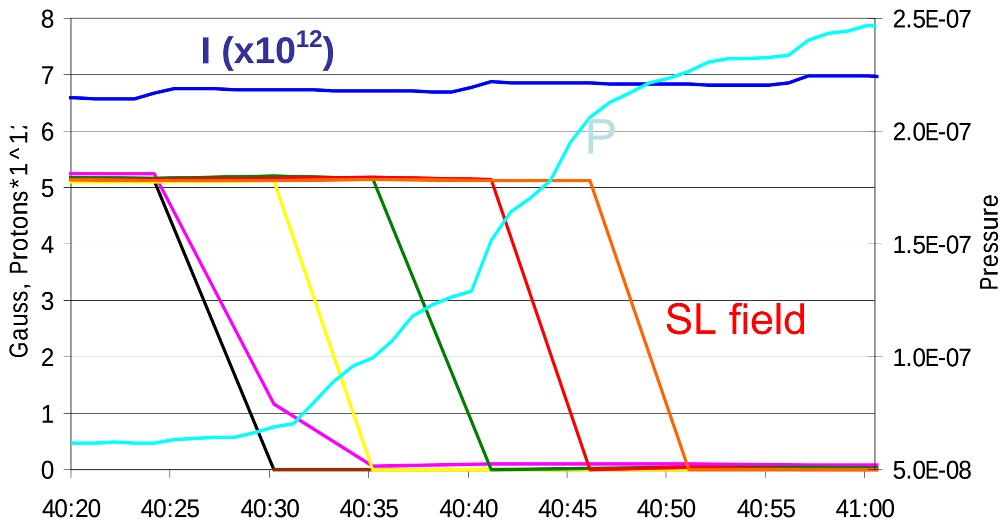
- Installed ~ 16 x 4 m in 2002
- 1.2 kW PS for every 4m
- Most at 12cm Φ Q3 - Q4 regions and bracketing electron detectors
- PVC or Kapton insulated solenoids
  - # 10 AWG, 212 turns/m
  - 2.7 Gauss/Amp (< 60 gauss)
- New solenoids at Phobos and Brahms in 2004 (~ 6m from IP)





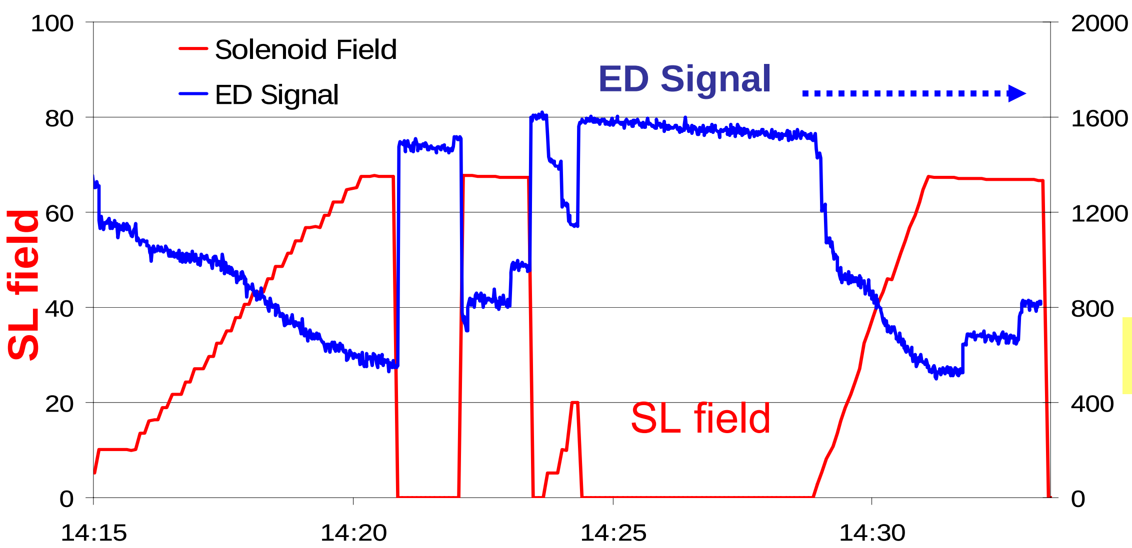
Upgrade in 2001 – 03'

Effectiveness of Solenoid in Reducing ΔP and e^-



Loralie Smart, Run-03 data

Pressure rise was reduced by x 4 with 5 gauss x 24m solenoid field



e^- signal was reduced by x 2 with 65 gauss solenoid field 20cm away from ED

Effect of SL is not dramatic!

Upgrade in 2004

Anti-Grazing Rings

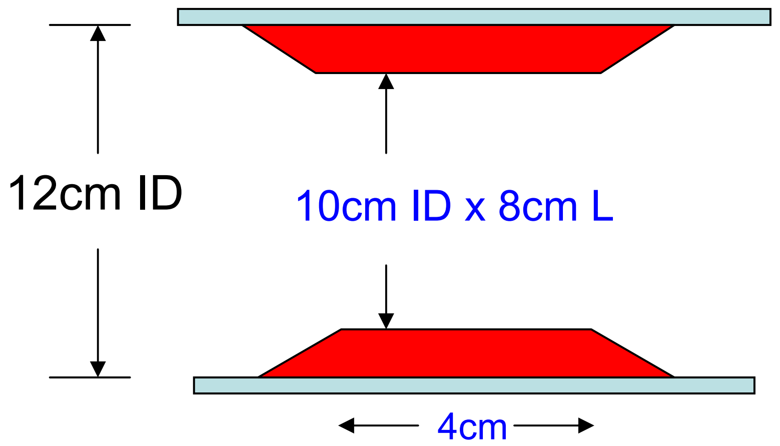
Thieberger, et. al,
PR-STAB, **7**, 093201 (2004).

To study the beam halo induced gas desorption

at grazing angle (no rings)

at normal incidence (with rings)

(a potential remedy for halo scrapping?)



Installed at two 12cm Φ “empty” sections

5 rings in each 22m section

11cm Φ @ 39.4m from IP

10cm Φ @ 44.6m, 48.0m, 53.8m and 59.0m

Use warm dipoles @ ~53.8m to kick the beam

Beam induced desorption yields can be estimated from $\int \Delta P * S\, dt$ and compared with 04’ studies

Possible comparison among the “empty” sections

Section	Anti-Graz	NEG	Beam direction
YO5:	with rings		outgoing
BI5:	with rings	with NEG	incoming
BO6:			outgoing
BO7		with NEG	incoming
YO8		with NEG	incoming

Upgrade in 2004

Cold Bore Pressure Rise

@ #5350 (1.5e11 x 110 bunches)

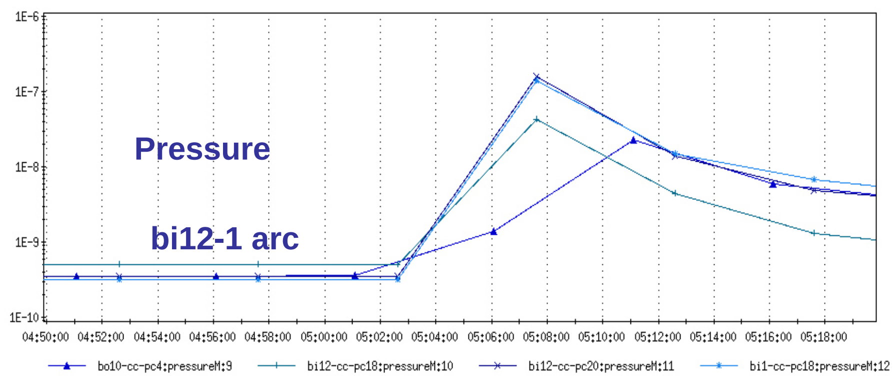
Observed large ΔP at many blue arcs and triplets

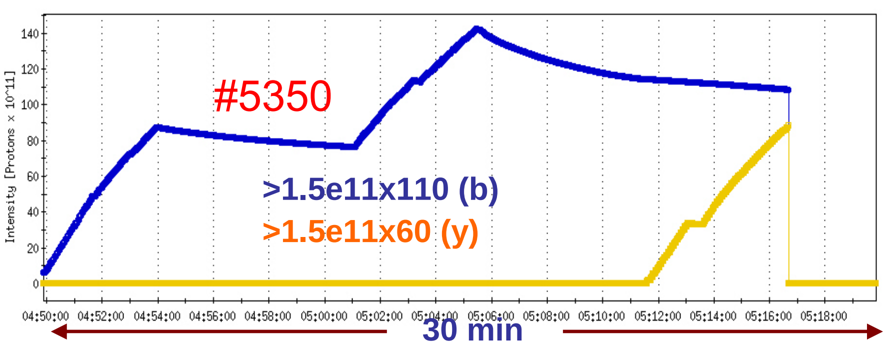
P_{beam} / P_o up to 10^3

No clear patterns vs. locations in the arcs

No confirmed ΔT (resolution to ~ 0.01ºK)

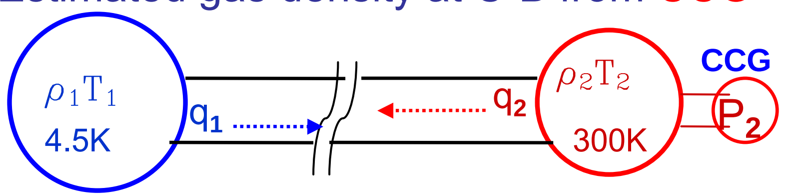
(0.01ºK ≈ 5 watt per 100 m)





CCG connected to 4.5ºK by
1”Φ x 1.5m conduit (C = ~1 *l/s*)

Estimated gas density at C-B from CCG



Assume the gas flux q_1 and q_2 reach equilibrium

$q_1 = \rho_1 v_1 \approx \rho_2 v_2 = q_2$

$\rho_1 T_1^{1/2} \approx \rho_2 T_2^{1/2}$

$\rho_1 \approx 8.2 \times \rho_2$

$\rho_1 / P_2 \sim 8.2$ for CO $(\rho_2 = P_2)$

$\rho_1 / P_2 \sim 18$ for H_2 $(\rho_2 = 2.2 \times P_2)$

Upgrade in 2004

Cold Bore Improvement for 05 Run

C-B were pumped down to ~1×10^{-3} Torr in yr 2000
Most at < 5×10^{-3} Torr after warm up to 80K (no He found) ⇒ H_2
< 1×10^{-1} Torr after warm up to R.T.
No active pumping of cold bore during shutdowns
No clear correlation between P_o (80K or R.T.) and ΔP @ #5350

Improvement in 04 shut down

Reduce P_o to < 1×10^{-2} Torr before cool down

(1×10^{-2} Torr at R.T. ≈ one monolayer (ML) after cool down)

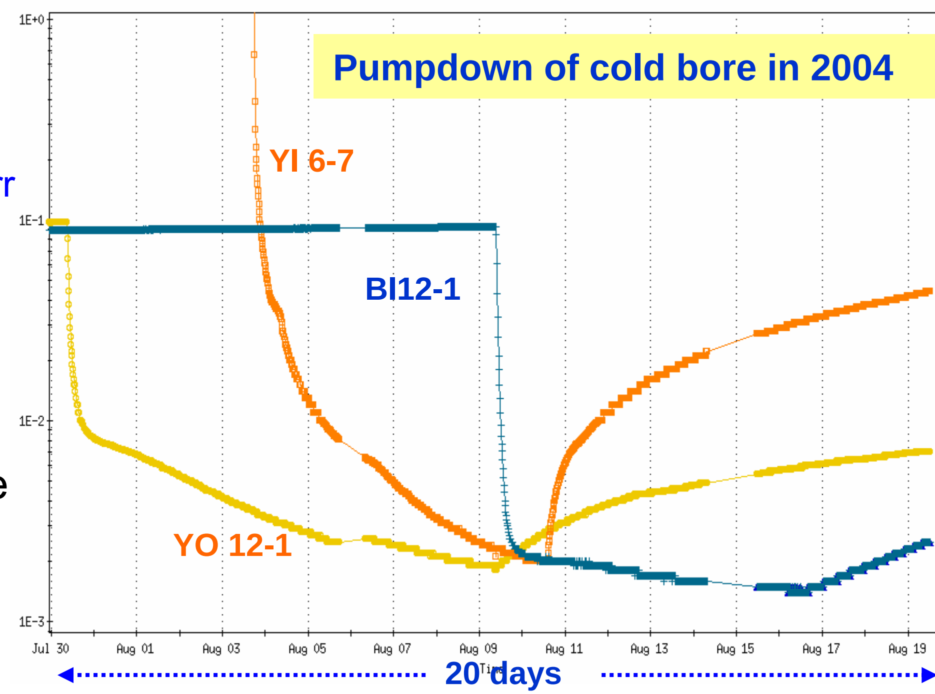
Pump down 6 triplets and 5 arcs (~ 25%) to < 10^{-3} Torr

Pressure will creep back to ~ 1×10^{-2} Torr after a few days

Pump one arc and one triplet after cool down to 80K

to below 1×10^{-7} Torr (to reduce H_2)

Compare ΔP vs P_o (RT or 80K) during 05 run



Reduce H_2 migration from warm bore to cold bore

Q (H_2) 1×10^{-9} Torr x 500 l/s x 7 months

= ~ 10 Torr.l

= One ML in Arcs,

= 10 ML in Triplets

Faster logging of C-B CCG and cryo Temp

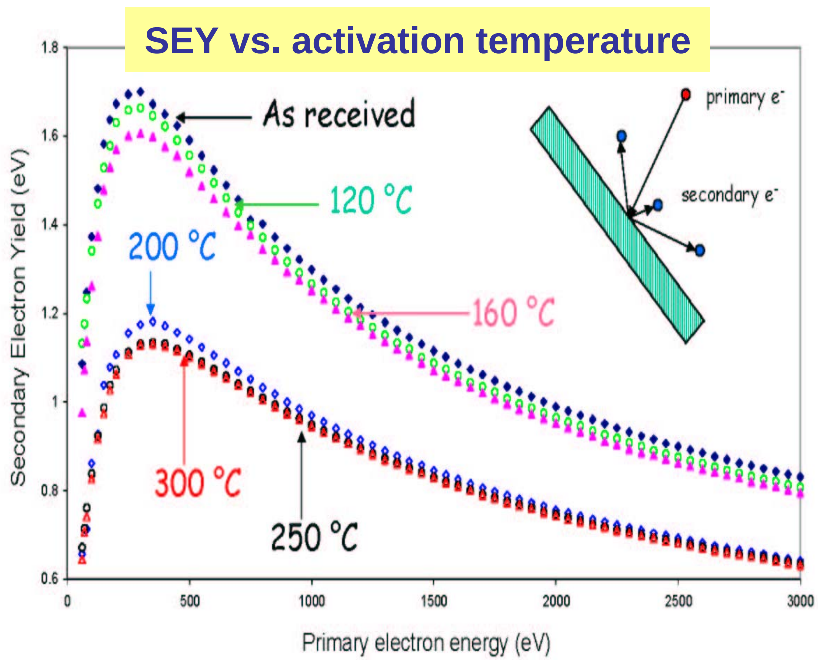
Upgrade in 2004

NEG Coating of Warm Beam Pipes

to reduce SEY, Electron Stimulated Desorption (ESD) and Provide Linear Pumping

⇒ Cure for Warm Pressure Rise?

NEG Coating ($Zr_{30}Ti_{30}V_{40}$ alloy) Developed at CERN
Coated by vendor SAES Getters (with license from CERN)
Installed 250m in 03’ and 04’ shutdowns at 12 cm Φ insertion regions
Will install 250m in 05’ shutdown



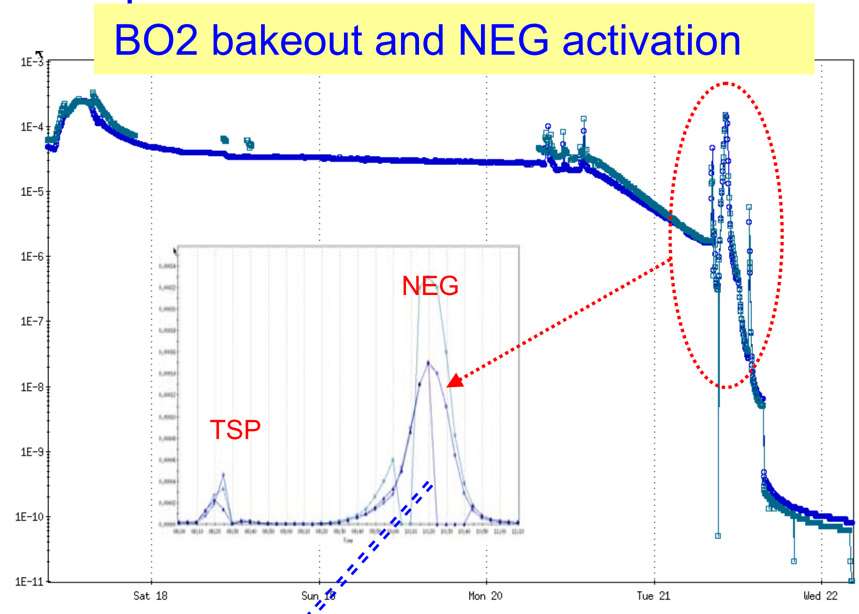
Secondary electron yield as a function of the primary electron energy for a Ti-Zr-V coating as received and after **2 hours** heating at 120, 160, 200, 250, and 300 °C

(P. Chiggiato, et. al., CERN)

SEY :	SS	> 2.0
	Be	~ 2.8
	NEG	~ 1.7 as received
	NEG	≤ 1.2 after activation
ESD:	SS:	10^{-2} - 10^{-1}
	NEG	~10^{-2} before activation
	NEG	~10^{-4} after activation
Pumping Speed:		
	IP+TSP	~200 *l.m/s* (12cm Φ)
	NEG	> 10^2 *l/s/m*

Upgrade in 2004

NEG Activation
with minimum gas adsorption



In-Situ Bake

Bake sections up to 250 C for 3 – 7 days

Pressure up to 1×10^{-3} Torr initially

NEG Activation

Maintain NEG pipes at ~ 100ºC during bake

to avoid saturation from desorbed gas

250 C x 1 hr at the end of bake cycle to activate

pressure up to 10^{-4} Torr during activation

Minimize active gas pumped during activation!

Lifetime capacity of 0.01 Torr.l/cm² **

S = 5 l/s.cm² for active gases (CO, H_2O…)

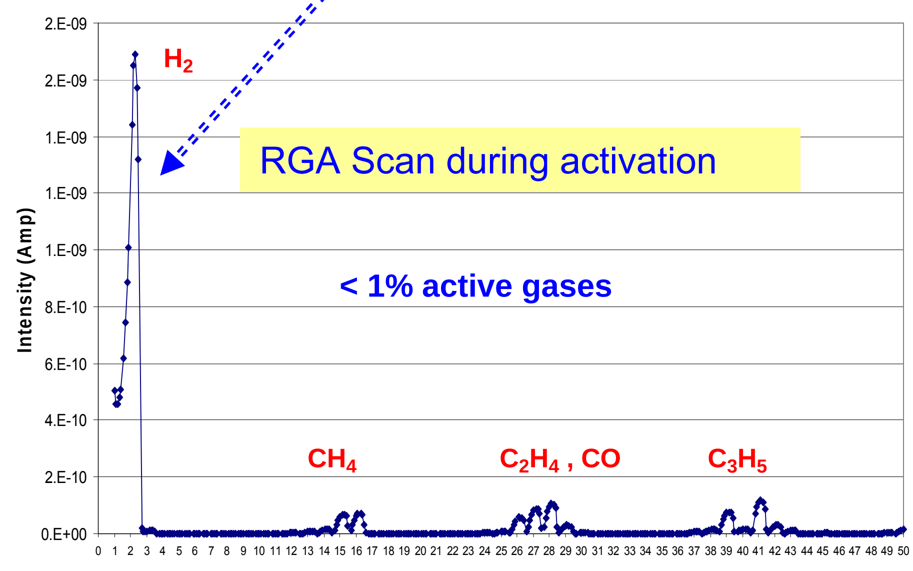
P_m = 2e-4 Torr for BO2 (with ~1% active gases)

Q = $\int$ S x P d t x 1%

= ~ 0.01 Torr.l/cm² for BO2 (worst case)

**1 µm thick NEG coating = 5e+18 atoms/cm²
has limited capacity for active gas
lifetime of ~ 10 activation cycles

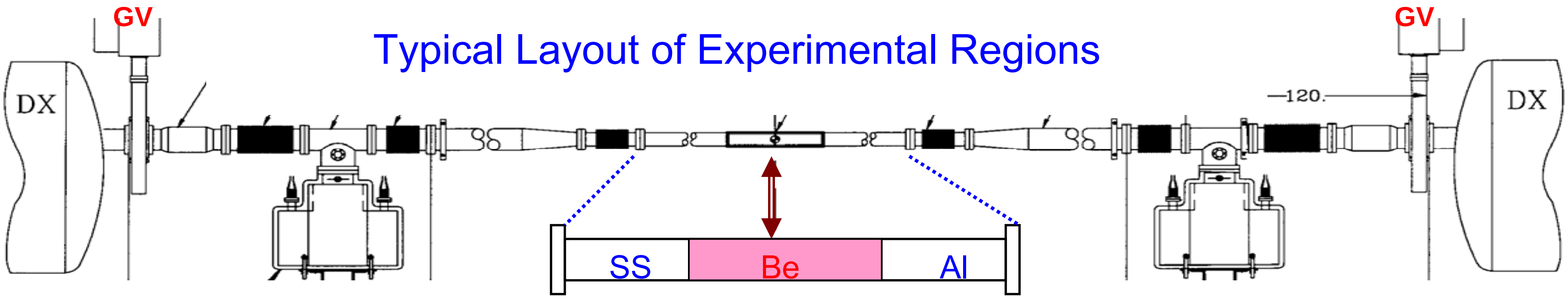
** NEG Poisoning at ~ 20% atoms = 0.01 Torr.l/cm²



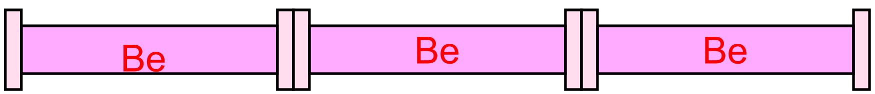
Future Plan / Summary

NEG Coating of Experimental Beam Pipes to Reduce SEY (η_{Be} ~2.8)

Typical Layout of Experimental Regions



Brahms, Phenix & Star: 7cm Φ x 1mm wall x 1.5m Be, brazed to Al or SS



Phobos: 7cm Φ x 1mm x 4m x 3 all Be with Be flanges and bolts

Big effort to activate and re-activate NEG at Phenix and Phobos

Can't activate the NEG for Star and Brahms (Al extension!)

NEG Coating by

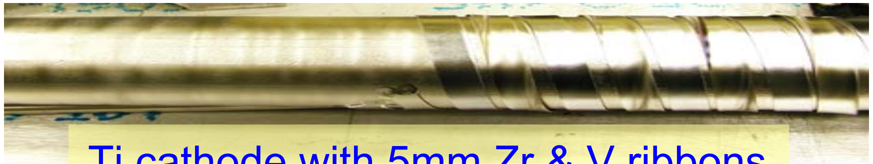
- SAES Getters – No!
  - Be, Length, Residual radiation
- CERN – Yes!
  - Up to 7m, Risk of Shipping
- BNL – R& D started
  - Preferred by experimenters

Expt.	L(m)	Be L(m)	Extension	Bake T (ºC)
Brahms	7.1	1.5	Al	150
Phenix	5.2	1.5	SS	200
Phobos	12	3 x 4		200
Star	8.2	1.5	Al	100

R. Todd, D. Weiss, P. He

BNL NEG Coating Development for Expt Beam Pipes
with Horizontal Cathode base on SNS experience

BNL SNS TiN coating setup


Ti cathode with 5mm Zr & V ribbons

SNS Ti cathode wrapped with 5mm Zr and V ribbons

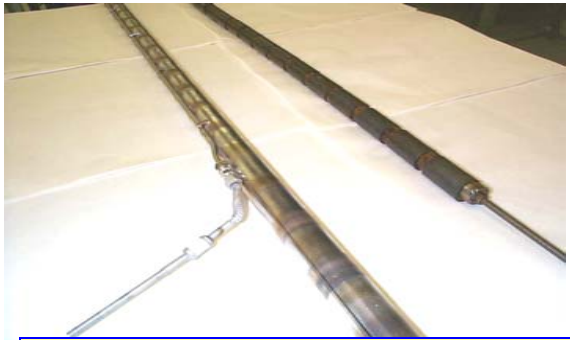
vs. vertical twisted wires and external solenoid at SAES, CERN

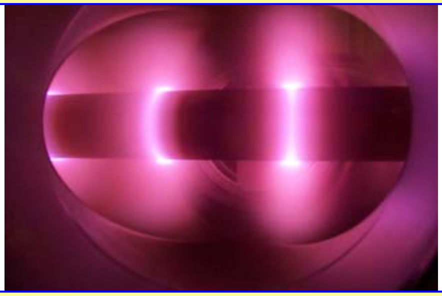
(cost, building, mounting, schedule, safety…)

1m long SS pipe coated, activated and reached low 10^{-11} Torr

Assembly of 4cm Φ x 6m cathode for 7cm Φ x 4m pipes

Difficulty in cathode mounting and alignment to obtain stable and uniform discharge ⇒ smaller cathode, smaller and shorter magnets…


Ti cathode and magnets


Magnetron sputtering plasma


NEG Coating Set Up for 4m x 7cm Φ pipes

Future Plan / Summary

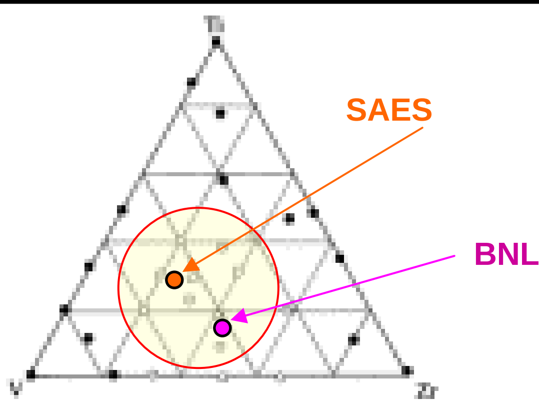
BNL NEG Coating Composition

CERN spec: $Zr_{30}Ti_{30}V_{40}$ ± 30%

SAES sample: $Zr_{25}Ti_{28}V_{47}$ by RBS

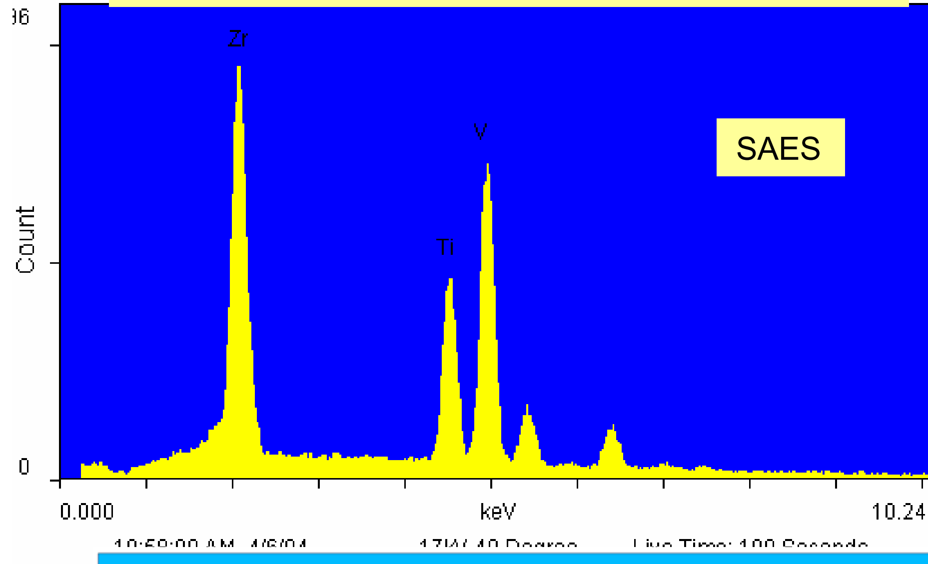
BNL samples: $Zr_{44}Ti_{16}V_{40}$ by RBS

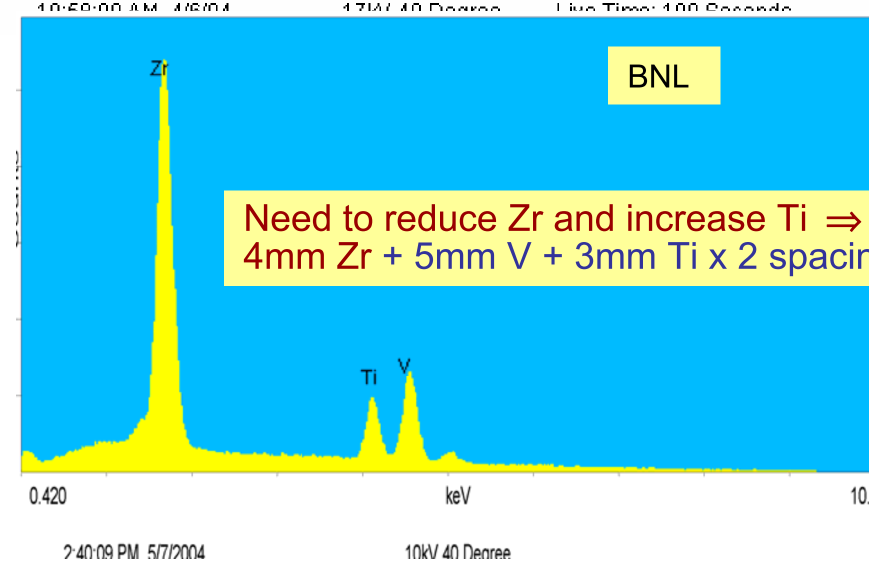
Sample	Measured by	Zr	Ti	V
SAES	EDS	38	24	38
SAES	AES	44	27	29
SAES	RBS	25	28	47
BNL	EDS	60	15	25
BNL	AES	56	19	24
BNL	RBS	44	16	40



Composition vs. activation/quality map

Energy dispersion X-ray spectroscopy (EDS)





Need to reduce Zr and increase Ti ⇒
4mm Zr + 5mm V + 3mm Ti x 2 spacings

Summary

- Pressure Rise at any section(s) becomes bottleneck for physics
- No single silver bullet: *In-situ* Baking, Solenoids,…
  - Lower P_o help reduce ΔP $\Rightarrow$ need thorough *in-situ* baking
  - Benefit of solenoids is limited!
- NEG coating for warm pressure rise
  - 12cm Φ pipes coated by vendor, install up to 500m by 2005
  - NEG coating of 7cm Φ IR Be pipes: by CERN or BNL R&D
  - IR Pipe Activation?
- Improvement of Cold bore vacuum
  - Pumping to $< 10^{-3}$ Torr before cool down
    - To reduce surface condensate to sub monolayer
  - Reduce H_2 migration from warm to cold